Grantee: UAF, Institute of Northern Engineering
Project Name: Safe and Efficient Exhaust Thimble

Grant and Project #1439/413007

Grant Completion Report

Background:

This report describes the testing of a new design for an exhaust thimble used for wood stoves, furnaces, diesel generators, and other high-temperature exhaust generating sources. The new design would replace the current technology with a passively cooled thimble that utilizes a thermal siphon to draw in cool outside air surrounding the hot exhaust stack and eliminates the open space between the indoor and outdoor environments. This design would prove most beneficial in northern regions, where significant heating loads and high energy prices make efficient building design particularly important.

Exhaust thimbles are protective sleeves that surround hot metal stovepipes or chimneys to protect a building from dangerously high temperatures. The UAF design improves on current technology, which allows air to pass freely between the interior and exterior of a building through the thimble annulus, the space between the thimble exterior and the hot stovepipe. The new design does not expose the interior and exterior environments to each other. Instead, cool exterior air circulates in the thimble annulus, which is sealed off from the interior of the building.

Activities: As part of the first round of funding of the Emerging Energy Technology Fund, the Institute of Northern Engineering (INE) at UAF designed, modeled, and built several prototypes of an exhaust thimble to improve building efficiency and eliminate uncontrolled airflow between a structure's interior and the outdoor environment. The prototypes were tested in a controlled setting to determine if the design functioned as intended and met necessary safety requirements.

The specific project tasks included:

- modeling of exhaust thimble steady-state operation with COMSOL Multiphysics;
- acquisition and setup of repurposed shipping container as testing lab;
- fabrication of 2-, 4-, 6-, and 10-inch internal diameter thimbles at UAF shop facility;
- testing and evaluation of performance of the four thimbles over a matrix of conditions including summer and winter ambient conditions, exhaust temperatures ranging from 400–1000°F, the presence and absence of wind; and various stages of occluded airflow within the testing thimble . Thermal imaging

was also used to document surface temperatures during some of the tests. Over 256 individual tests were conducted over the various combinations of thimble sizes and conditions.

The project's testing activities began in February 2013 with the purchase of the data acquisition system and fabrication of the 2-inch-diameter thimble, used for initial testing. The data acquisition system was tested during the fall of 2013. All remaining thimbles were built and tested between late fall 2013 and the end of 2014.

ACEP assisted INE with review of data collection protocol, review of draft reports and analyses and in the preparation of the final report.

Project Costs: Expenditures of $48,578 were incurred in the conduct of this grant.

Progress Report Expenditures

	Funding	Expenditures*	%
Denali Commission:	$40,429.00	$19,542.44	48%
Other Funding:	$53,253.00	$29,035.77	55%

Project Outcomes: Testing Conclusions
* All thimble temperatures remained below the 400°F pyrolysis danger level where the thimble intersects the roofline.
* Wind had limited effect on thimble performance.
* Thimble annular occlusion limited air circulation, but temperatures still remained at safe levels.
* The 6-inch thimble had the highest temperatures at the roof intersection, followed by the 10-inch, 4-inch, and 2-inch thimbles.

- General cost estimates for thimble fabrication obtained from a local sheet metal company in Fairbanks ranged from $1400 to 2400 per unit depending unit diameter, length, materials and order quantity.

Problems Encountered: In general, very few problems were encountered with the execution of this grant. One minor issue was the limited success in the measurement of airflow velocity through the thimble annular vent channels during testing. To better understand air circulation within and around the thimble, successful velocity measurements obtained throughout the entire testing process would be useful.

Conclusions and Recommendations: Testing at UAF has provided a good first step towards product development. The testing conducted during this study showed that during the testing conditions replicated in the laboratory with exhaust gas temperatures up to 1000°F, the temperatures where the thimble made contact with building materials stayed below 400°F, the critical temperature at which pyrolysis starts to occur. There are NFPA standards which will need to be revised in order for this product to meet building codes which is a significant step to becoming commercially viable.

Future independent third party testing would be required before the exhaust thimble could be installed in homes and businesses. Discussions with UAF researchers revealed that they do not intend to develop the product. They think that private industry is best equipped to commercialize the UAF design and pursue further development.

Future testing should include data collection and analysis with a focus on the following:

* Thimble temperatures.
* Air velocities measured at various places in the thimble cooling chamber during a variety of exhaust gas temperatures. These measurements will verify the modeling that has been performed to date.
* A more in-depth look at thimble costs and the economics of replacing existing exhaust thimbles with this new and improved exhaust thimble.